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E. A. STROMBERG, *Editor*

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The reports of research published in this magazine are necessarily qualified by the conditions of the tests from which the data are obtained. Whenever it is deemed possible to do so, generalizations are drawn from the results of the tests; and, unless this is done, the conclusions formulated must be considered as specifically pertinent only to described conditions.

In This Issue

Page

Experimental Sand-Clay Base Course in North Carolina 299
Speed Transition Ramps on a Bridged Rotary 307
Twenty-Five Years of Farm Truck Ownership 312

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EXPERIMENTAL SAND-CLAY BASE COURSE IN NORTH CAROLINA

BY THE DIVISION OF PHYSICAL RESEARCH, PUBLIC ROADS ADMINISTRATION

Reported by **JAMES A. KELLEY**, Associate Highway Engineer

THE PURPOSE of this investigation was to study, by construction and observation of an experimental road, the effect of variations in plasticity index on the service behavior of base courses composed of sand-clay mixtures. Investigations made in the laboratory by means of the circular track and the experience of various highway departments in the construction of this type of base course indicated that the plasticity index for such materials should not be greater than 6. Therefore, sand-clay mixtures having plasticity indexes both above and below 6 were specified in this investigation in order to provide information as to pavement life over a wide range of materials and to corroborate or disprove the laboratory findings.

The experimental road was constructed under contract by the North Carolina State Highway and Public Works Commission in cooperation with the Public Roads Administration. Base construction was started in August 1936 and was completed in May 1937. A bituminous surface treatment with cotton-fabric reinforcement was applied in June 1937.[1]

DESCRIPTION OF EXPERIMENTAL ROAD

The section of road selected for the experiment is located on State Highway No. 403 in Sampson and Duplin Counties, North Carolina, and is designated as Federal-aid projects 468A and B. It begins near the east city limits of Clinton and extends in an easterly direction for a distance of 14½ miles to Faison. It passes through an area of level to gently rolling topography, crossing three major stream valleys with their adjacent swampy bottom lands. The average daily traffic recorded in 1941 ranged from 660 to 1,020 vehicles.

The experimental road was divided into four sections varying from 3 to 5 miles in length. Sections having plasticity indexes of 2, 6, 8, and 14 were specified after a detailed soil survey of the roadbed and the borrow pits had been made. The sand and clay soils were combined in such a manner that the resulting mixtures had plasticity indexes within a range of ±2 of the specified value. Details of the various sections are given in table 1.

TABLE 1.—*Details of experimental sections*

Section	Length	Base thickness	Plasticity index	
			Design	Range [1]
	Miles	*Inches*		
1	3.13	[2] 7	6	4–8
2	5.05	[2] 7	8	6–10
3	3.16	[2] 7	14	12–16
4	3.21	7	2	0–4

[1] Range allowed for a tolerance of ±2 from the design plasticity index.

[2] Base thickness was increased to 10 inches, owing to poor drainage conditions, on 0.38 mile of section 1 ,0.23 mile of section 2, and 0.23 mile of section 3.

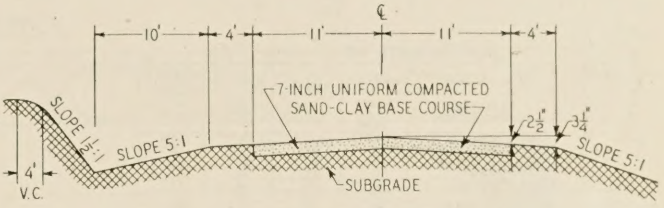

FIGURE 1.—TYPICAL CROSS SECTION OF THE EXPERIMENTAL ROAD.

A 7-inch uniform thickness of base (fig. 1) was specified for the entire experimental road. However, a soil survey disclosed the need for additional base thickness at four locations where it was evident that adverse conditions would affect the road performance very appreciably. Two of these locations were in section 2 and one each in sections 1 and 3. The base thickness was increased to 10 inches at these locations.

Sections 2, 3, and 4 had been constructed to improved line and grade in 1935 and a sand-clay surfacing of variable composition had been placed in a trench section, 18 feet wide by 6 inches deep, at that time. Preparation of the new base on these sections required the addition of sufficient material from the soil pits to increase the width to 22 feet and the thickness to 7 inches.

Section 1 followed generally the location of an old unsurfaced county road. Grading was necessary to provide satisfactory lines and grades prior to constructing the base course. Since there was no old sand-clay surfacing on this section, the experimental base was constructed entirely of material hauled in from selected soil pits and blended to produce the desired mixture.

DESCRIPTION OF SOILS

A detailed soil survey disclosed that the road is located almost entirely on the sandy loams of the Norfolk, Portsmouth, and Ruston series. Clays were encountered in the low swampy areas and on the slopes adjacent to the stream bottoms. The distribution of the various soils over a portion of the experimental road and the results of laboratory tests performed on typical samples are shown in figure 2. This information is representative of the soil conditions on the entire experimental road.

With the exception of the soil designated as undeveloped clay, all of the soils had physical characteristics of the A–2 friable or A–2 plastic groups. The undeveloped clay had physical properties typical of the A–7 group.

A fine sandy loam surface soil and a sandy clay subsoil are common to the profiles of the Norfolk, Portsmouth, and Ruston series. Materials for the base

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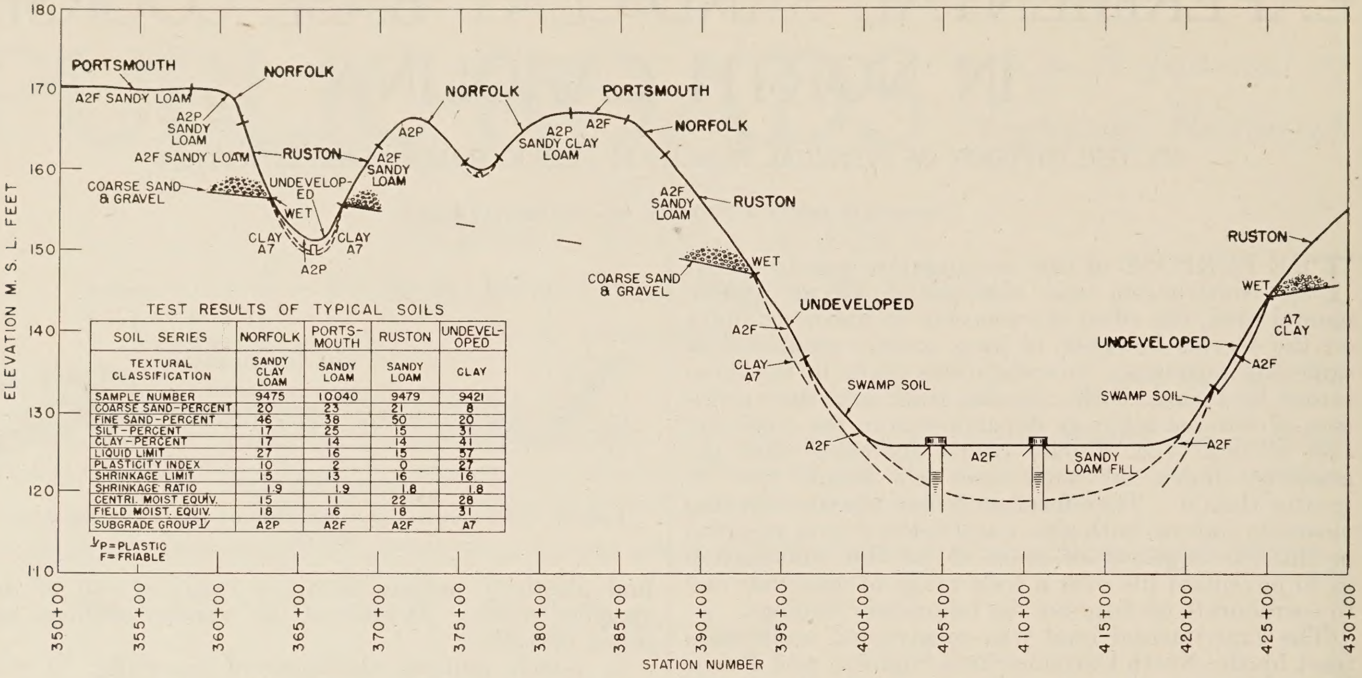
[1] The base course was originally planned in conjunction with the study of the effect of cotton-fabric reinforcement on the service behavior of thin bituminous surface treatments. The results of this cotton-fabric experiment and others are reported in *Cotton Fabric in Bituminous Construction* by Paul F. Critz; PUBLIC ROADS, vol. 24, No. 10, Oct.-Nov.-Dec. 1946, p. 251. The cotton-fabric reinforcement had no effect, beneficial or otherwise, on the performance of the road surface; and this report is devoted entirely to the influence of variations in the quality of the sand-clay base course.



TEST RESULTS OF TYPICAL SOILS

SOIL SERIES	NORFOLK	PORTSMOUTH	RUSTON	UNDEVELOPED
TEXTURAL CLASSIFICATION	SANDY CLAY LOAM	SANDY LOAM	SANDY LOAM	CLAY
SAMPLE NUMBER	9475	10040	9479	9421
COARSE SAND-PERCENT	20	23	21	8
FINE SAND-PERCENT	46	38	50	20
SILT-PERCENT	17	25	15	31
CLAY-PERCENT	17	14	14	41
LIQUID LIMIT	27	16	15	57
PLASTICITY INDEX	10	2	0	27
SHRINKAGE LIMIT	15	13	16	16
SHRINKAGE RATIO	1.9	1.9	1.8	1.8
CENTRI. MOIST EQUIV.	15	11	22	28
FIELD MOIST. EQUIV.	18	16	18	31
SUBGRADE GROUP[1]	A2P	A2F	A2F	A7

[1] P=PLASTIC
F=FRIABLE

Figure 2.—Portion of Soil Type Profile, and Test Results of Typical Soils.

course were obtained from borrow pits located in the soil of these series. These materials varied from nonplastic sands to sandy clays having plasticity indexes as high as 25.

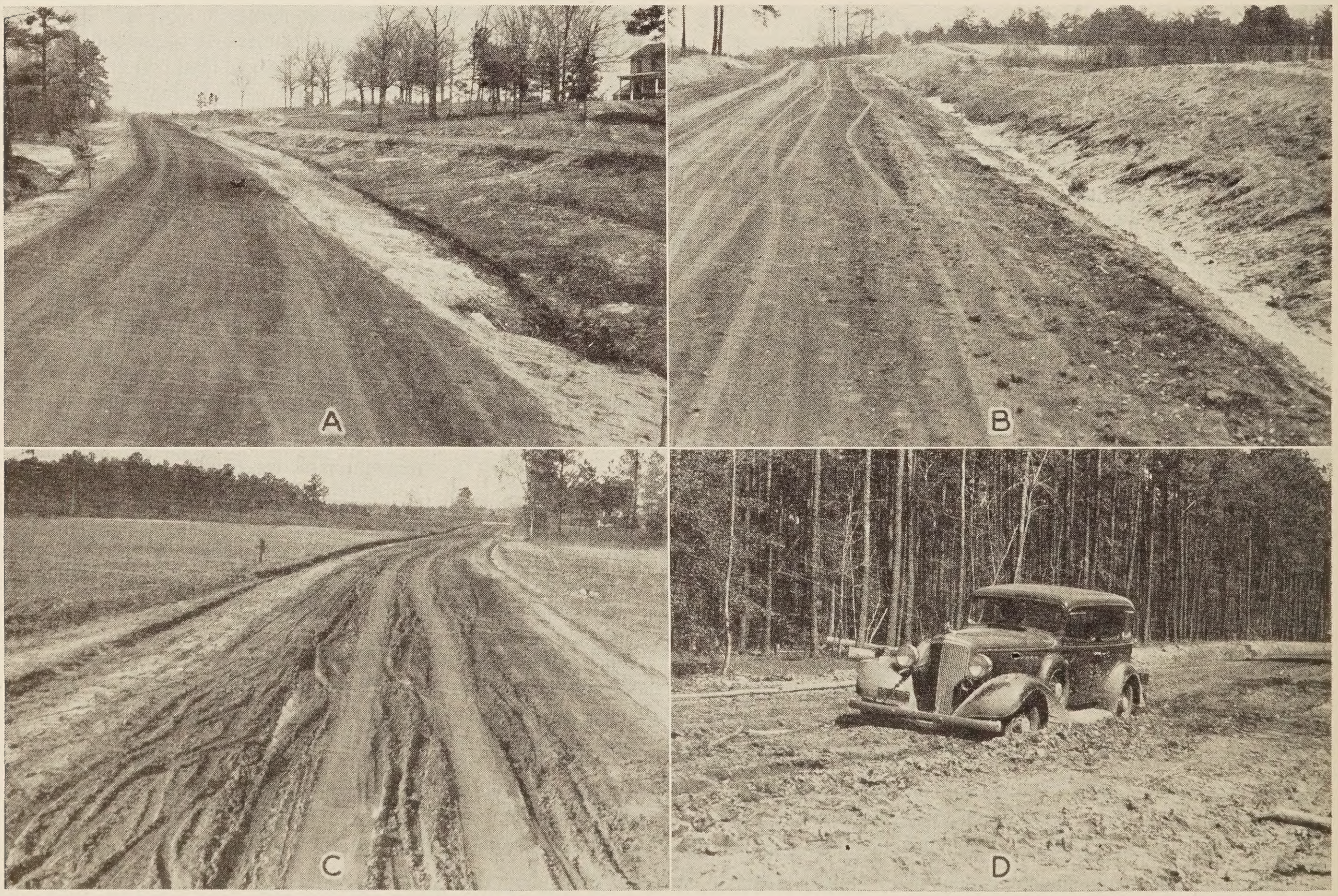


Figure 3.—Poor Performance of Original Sand-Clay Surfacing: (*A*) Outlet of Porous Stratum Causing Unstable Area; (*B*) Water Flowing From Sandy Stratum in Sidehill Cut; (*C*) Poorly Drained Area in Portsmouth Soil; (*D*) Unstable Roadway in High Water Table Area.

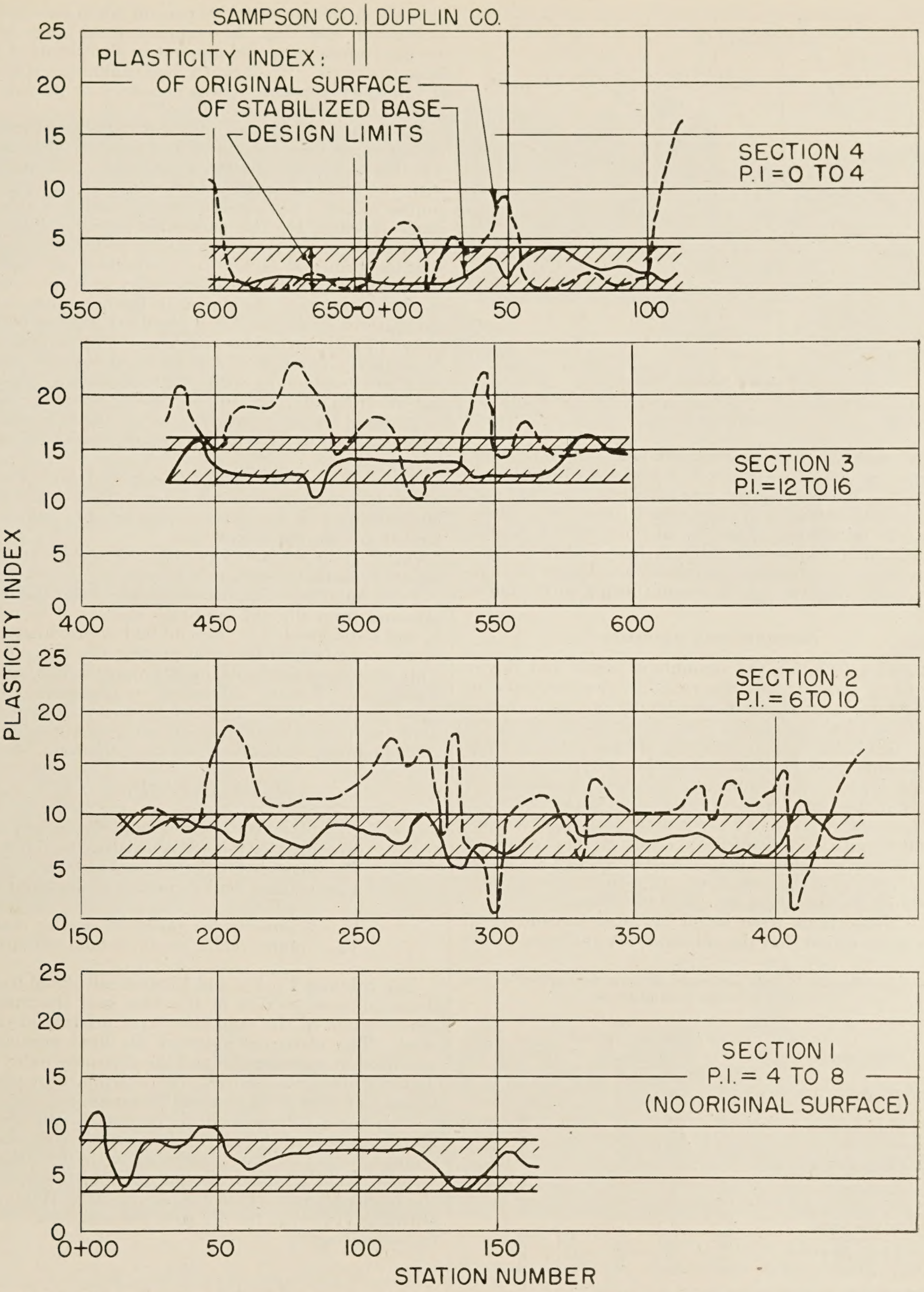


Figure 4.—Plasticity Index Determinations of the Original Surface, the Design Limits, and of the Stabilized Base as Actually Constructed.

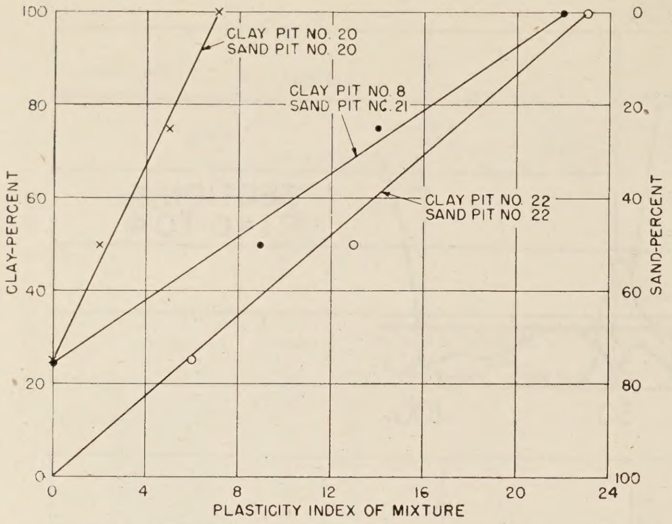


Figure 5.—Materials Proportioning Curves Based on Plasticity Index.

Performance of the original sand-clay surfacing constructed in 1935 on sections 2, 3, and 4 is illustrated in figure 3. Where drainage was adequate, the road surface was maintained in satisfactory condition. However, the occurrence of springs in the roadbed, sidehill seepage, and high water table in low, poorly drained areas resulted in localized mudholes and longer sections of unstable roadway which became deeply rutted under traffic.

PROPORTIONING MATERIALS

Before calculating the amounts of sandy and clayey soil to be hauled onto the road, it was necessary to explore the borrow pits thoroughly for quantities available and to obtain samples to determine their gradations, liquid limits, and plasticity indexes. On sections 2, 3, and 4, the existing sand-clay surface was also sampled and tested and its thickness measured for determination of volume of material in place.

Plasticity indexes of the existing sand-clay surface, together with the plasticity indexes of the completed base course, are shown graphically in figure 4. Gradations and physical constants of typical base-course materials and mixtures are given in table 2.

All proportions were based on loose measurement. It was estimated that the old sand-clay surfacing would increase in volume about 50 percent when scarified and pulverized, and that the compacted thickness of the designed mixtures would amount to two-thirds of their loose thickness. To obtain a final compacted thickness of 7 inches, therefore, it was necessary to provide 10½ inches of loose material.

Table 2.—*Results of tests performed on samples typical of base course materials and mixtures*

Sample location	Percent passing sieve indicated				Liquid limit [1]	Plasticity index [1]
	No. 4	No. 10	No. 40	No. 200		
Borrow pit soils:						
Clay pit No. 8	100	96	56	37	52	22
Clay pit No. 20	100	100	67	32	27	7
Sand pit No. 21	100	97	56	25	NP	NP
Sand pit No. 23	100	97	62	7	NP	NP
Existing sand-clay base on old road:						
Section 2, sta. 230	100	92	54	26	37	11
Section 3, sta. 435	100	93	58	35	44	20
Section 4, sta. 650	100	86	56	23	NP	NP
Completed base course:						
Section 1, sta. 125	100	95	53	22	27	6
Section 2, sta. 220	100	98	67	23	29	8
Section 3, sta. 577	100	93	70	31	37	14
Section 4, sta. 78	100	93	73	26	18	2

[1] NP=nonplastic.

The volume of borrow material required to produce the specified base thickness was first determined. It was then necessary to select a soil that, when combined with the material in the road, would produce a base-course mixture having a plasticity index within the range specified for the particular section. The plasticity index of the sand-clay placed on the road in 1935 was the principal factor in determining the limits of the sections and the plasticity index to be obtained in the final mixture. As shown in figure 4, most of the old material in section 2 had plasticity indexes between 9 and 15 with variations as low as 0 and as high as 18. A plasticity index of 8 was specified for this section. Similarly, section 3, with material having plasticity indexes from 10 to 22, and section 4, consisting largely of material having plasticity indexes between 0 and 5, were designed to have final plasticity indexes of 14 and 2, respectively.

A plasticity index of 6 was specified for section 1, which had no previous sand-clay surface. All of the material used in the base course on this section was hauled in from the borrow pits.

On all four sections, a tolerance of ±2 from the selected plasticity index was allowed.

Tests on a large number of samples from the borrow pits and from the old sand-clay surface of sections 2, 3, and 4 disclosed that they all had approximately the same percentage of material passing the No. 40 sieve. This simplified the problem of proportioning by eliminating the effect of differences in gradation. Under these conditions, the required plasticity indexes of the different materials are proportional to their volumes.

The relation is expressed by the equation:

$$V_F P_F = V_E P_E + V_A P_A \text{------------} \quad (1)$$

where:
P_A = plasticity index of material to be added,
P_E = plasticity index of existing material
P_F = plasticity index of final mixture,
V_A = volume (cubic yards) of material to be added,
V_E = volume (cubic yards) of existing material,
V_F = volume (cubic yards) of final mixture.

The volumes V_A, V_E, and V_F were calculated from the designed cross section of the base and the measured cross section of the sand-clay layer existing in the old road. The plasticity index of the final mixture, P_F, was fixed by specification and the plasticity index of the material in the old road, P_E, was determined by means of laboratory tests on representative samples.

Therefore, it remained to determine the required plasticity index, P_A, of the borrow pit soil having a volume, V_A, that, when combined with the other materials, would produce the specified plasticity index in the final mixture. Transposing equation (1) and substituting $(V_F - V_A)$ for V_E gave the following equation for estimating P_A:

$$P_A = P_E + \frac{V_F}{V_A}(P_F - P_E) \text{----------} \quad (2)$$

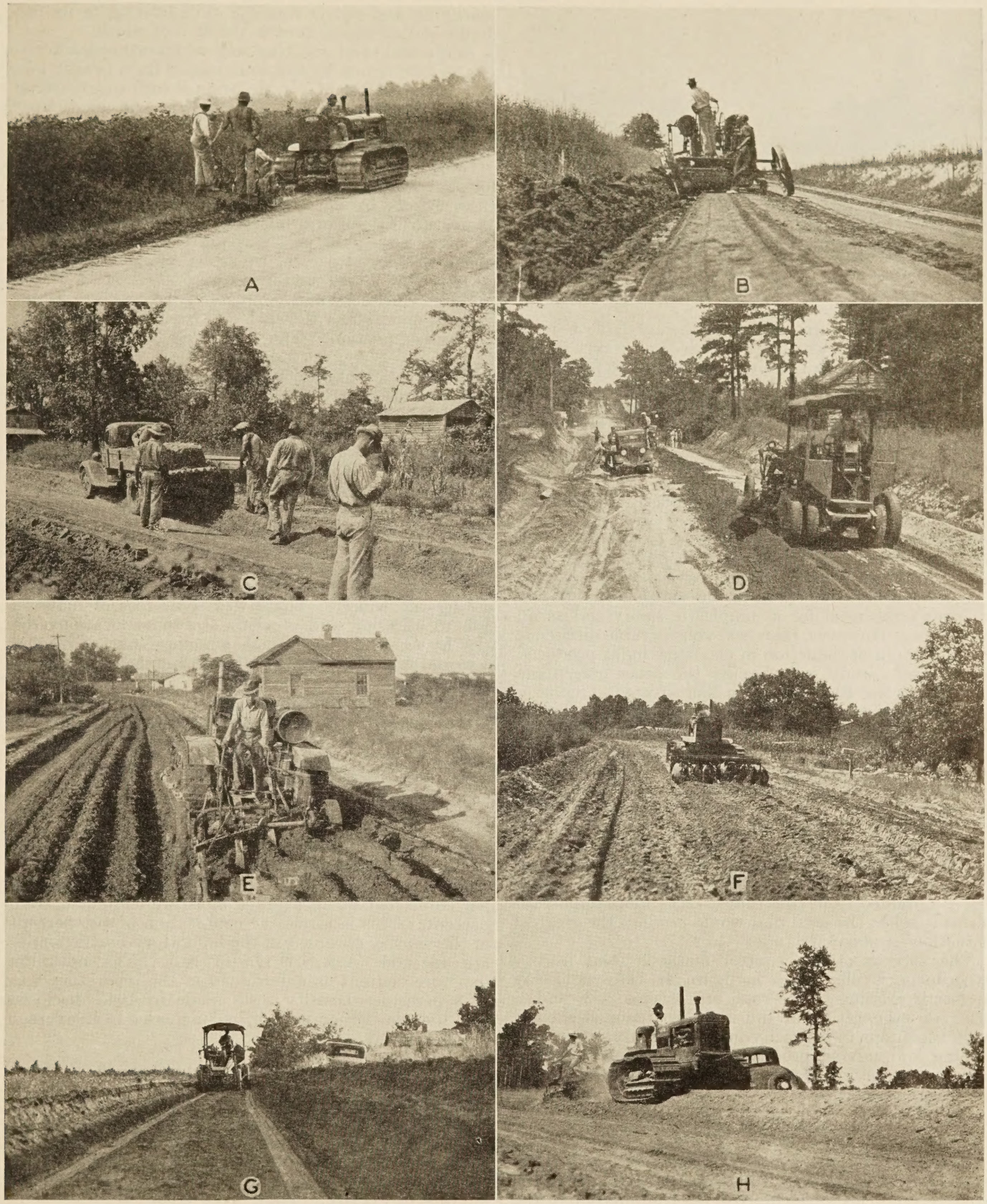


Figure 6.—Construction of Sand-Clay Base Course: (*A*) Scarifying Old Roadway and (*B*) Removing Material to Widen Trench Section; (*C*) Distributing and (*D*) Spreading New Material From Borrow Pits; (*E*) Plowing Original Surface and Added Material; (*F*) Pulverizing With Disk Harrow; (*G*) Mixing Original and Added Material With Motor Grader; (*H*) Pulverizing With Disk Harrow During Mixing Operation.

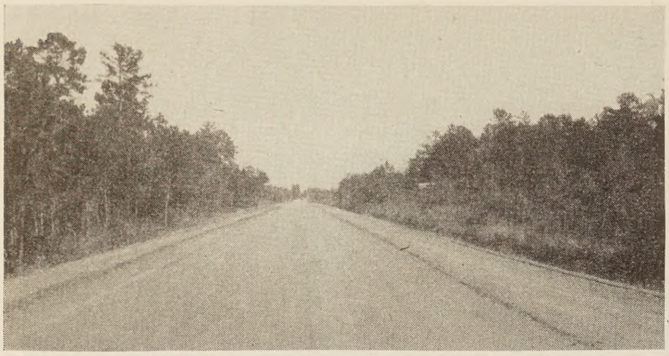


Figure 7.—The Compacted Stabilized Base Prior to Application of Bituminous Surfacing.

When material from any one of the available borrow pits did not furnish a soil of the desired plasticity index, the materials from two pits were combined to produce a mixture having the specified plasticity index. The proportions from each of these pits were determined from curves developed from the results of tests performed on several combinations of the two materials. Figure 5 shows three of the curves used in proportioning materials for this experimental road.

In many instances, a negative value of P_A was obtained as a mathematical result in the solution of equation (2). A nonplastic material is one for which the plastic limit equals or exceeds the liquid limit. The latter condition results in a negative plasticity index. Therefore, a negative result in the solution of equation (2) shows the need for a nonplastic sandy soil as an admixture. However, there was considerable difference in the amount of reduction in plasticity index produced by different sandy soils having the same percentage passing the No. 40 sieve. This is illustrated in figure 5. The sand from pit No. 21 was more effective in reducing plasticity index than was the sand from pits Nos. 20 and 22. The plasticity index of clay from pit No. 8 was reduced from 22 to 0 by an admixture of 75 percent of sand from pit No. 21. In contrast, the plasticity index of clay from pit No. 22 was reduced from 23 to 6 with an admixture of 75 percent of sand from pit No. 22. It required an admixture of 75 percent of sand from pit No. 20 to reduce the plasticity index of clay from pit No. 20 from 7 to 0. The greater the negative value of P_A, as obtained from equation (2), the more important it was to select the sand that would produce the greatest reduction in plasticity index.

The success of the control methods used in this experiment is illustrated in figure 4. The sand-clay materials existing in the road on sections 2, 3, and 4, prior to preparation of the new base course, showed wide variations in plasticity index. Control of proportioning and mixing produced, with rare exceptions, a base course having plasticity indexes within the specified tolerance of ±2.

CONSTRUCTION METHODS

Base construction on sections 2, 3, and 4 required the excavation of a trench 2 feet wide on each side of the existing sand-clay surfacing and the combination of the surfacing material with additional soil from selected pits to produce a base 7 inches in thickness and 22 feet wide, as shown in figure 1. This was accomplished by scarifying the shoulder material (fig. 6*A*) and removing it by means of a blade grader (fig. 6*B*), followed by scarifying and pulverizing the old surfacing to its full depth and spreading it over the 22-foot width.

Additional sand and clay soils of known characteristics as determined by test were hauled from nearby pits and deposited (fig. 6*C*) on the original surfacing material in quantities calculated to give the specified cross section after compaction. Spreading was performed by motor grader (fig. 6*D*).

Gang plows, harrows, and motor graders were used for pulverizing and mixing the different materials (figs. 6*E*, *F*, *G*, and *H*). These operations were continued until a uniform mixture was obtained and until all materials would pass through a 1¼-inch sieve and not more than 14 percent would be retained on a No. 4 sieve. The mixed materials were then spread to a uniform thickness and compacted by traffic. Motor graders maintained the surface with the proper crown during compaction. The completed base is shown in figure 7.

Construction of section 1 was performed in the same manner except that all of the material used in the base course was obtained from borrow pits.

Approximately 54 percent of the work was completed by November 1936 when the job was shut down for the winter. Section 2 and portions of sections 1 and 3 had been compacted and shaped to final cross section. In order to protect the subgrade on the remainder of the experimental road, all of the required borrow material was hauled in and partially mixed so that the road would be passable during the winter.

The road was maintained by blading and dragging during the winter. There was some loss of material due to abrasion and erosion. In some locations the loss by erosion was in such amounts that additional material was necessary to bring the base up to its required thickness.

Final mixing and compaction on these sections was started in April 1937, and the base was ready for the application of the cotton fabric and the bituminous surface in May. The total thickness of the bituminous surface was three-fourths of an inch.

BASE COURSE DENSITY

Base course densities and moisture contents were measured just prior to construction of the bituminous surface treatment. The base averaged 120.3 pounds per cubic foot at an average moisture content of 10.6 percent. This is a relative compaction of 101 percent of the density obtained in the laboratory by the standard method (A.A.S.H.O.) of test. The optimum moisture content as determined in the laboratory was 11.8 percent. Density tests made in 1945 disclosed that the relative compaction had increased to an average of 105 percent.

PERFORMANCE OF EXPERIMENTAL ROAD

Condition surveys to determine the service behavior of the base were made in December 1937, October 1938, March 1940, and September 1945. The results of these surveys are shown graphically in figure 8. A few failures were observed in December 1937, after 6 months of service. They were small local areas in sections 2 and 3 where the subgrade had become unstable as a result of seepage or high water table. By October 1938, the failures in these wet locations had developed to the point where it became necessary to excavate the subgrade, base, and surfacing and replace

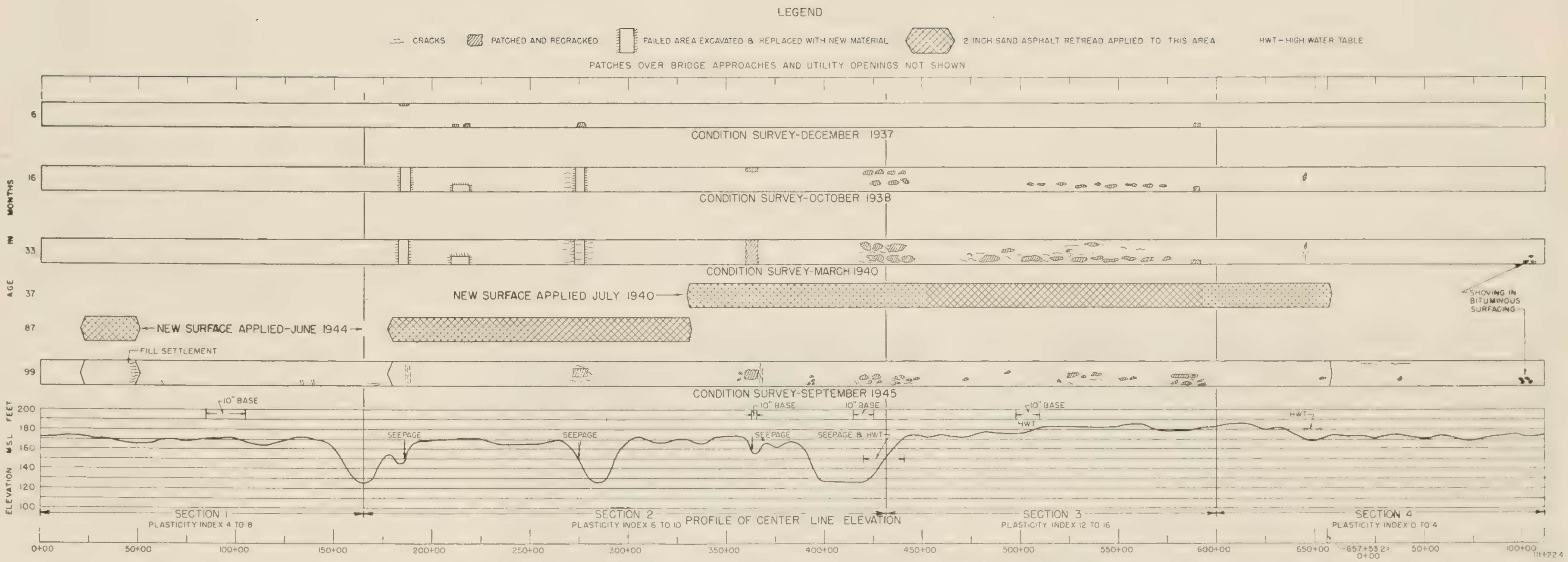


FIGURE 8.—CONDITION SURVEYS AND PROFILE OF THE EXPERIMENTAL ROAD.

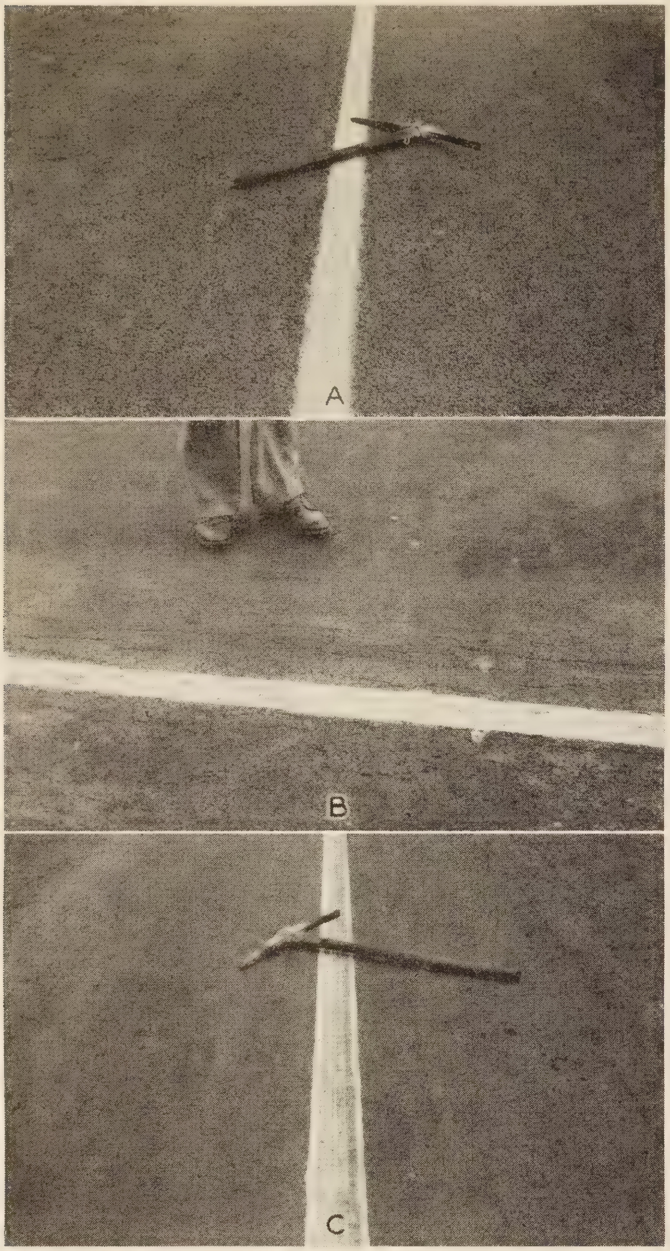


Figure 9.—Eight Years After Construction, (*A*) The Original Surfacing Was Still in Good Condition on Section 4, (*B*) The 1940 Resurfacing on Section 3 Had Cracked, and (*C*) The 1944 Resurfacing on Section 2 Was in Good Condition.

them with new material. Numerous patches were required in section 3 where the surfacing failed owing to deformations in the base course. There were no failures in section 1, and only one small patch was needed in section 4 in an area of poor drainage.

In March 1940, section 1 was still free of failures but section 4 had developed two small rough areas and required small patches. Cracking, rutting, and breakage had developed on 80 percent of section 3 where the base course had plasticity indexes ranging from 12 to 16. The rebuilt areas in section 2 were starting to crack and the breakage was spreading to the adjacent surface.

By the summer of 1940, after about 3 years of service, maintenance of the areas where failures had occurred had become such a problem that a new bituminous surface was constructed on parts of sections 2 and 4 and all of section 3. The new surface consisted of a mixture of 5½ percent of RC–2 cut-back asphalt with local sand in sufficient quantity to provide a thickness of 2 inches.

In June 1944, the new bituminous surface was extended to include most of section 2 and a small part of section 1. The new surface was applied in sections 1 and 4 because of the roughness that had developed, probably as a result of additional base compaction or fill settlement.

Failures previously described in sections 2 and 3 were showing up through the new surface when the final survey of this experimental road was made in September 1945. A small amount of cracking was also observed in sections 1 and 4.

Figure 9*A* shows the good condition of the original surface on section 4 at a point where the plasticity index of the base was 1. Figure 9*B* shows the 1940 resurfacing on a portion of section 3 where the plasticity index was 15—it will be noted that cracking had already recurred. Figure 9*C* shows the 1944 resurfacing, in good condition, at a point on section 2 where the plasticity index was 8. These photographs were made at the time of the final survey.

SUMMARY

The observations of the construction and performance of this experimental road may be summarized as follows:

1. Group A–2 plastic and A–2 friable soils comprised the subgrade on the entire length of the road. Group A–7 soils encountered in low areas were covered during grading operations with fills composed of A–2 soils.
2. Subsurface water in the form of seepage or high water table was responsible for the unstable subgrade conditions encountered. Increasing the thickness of base to 10 inches did not overcome the effects of these moisture conditions.
3. Failures occurring in the bituminous surface were the result of high plasticity index of the base course as well as unstable subgrade caused by poor drainage.
4. The base course in section 3, having a plasticity index of 12 to 16, was definitely unsatisfactory. Sections 1 and 4 with plasticity indexes ranging from 4 to 8 and 0 to 4, respectively, were satisfactory.
5. Except for failures caused by inadequate drainage, the base course on section 2, having a plasticity index range of 6 to 10, was generally in good condition. However, the fact that a new bituminous surface 2 inches in thickness was placed over practically its entire length as a maintenance measure indicates that the performance of this section was not entirely satisfactory. In this connection, plasticity indexes greater than 6 have given good results in other instances under favorable drainage and climatic conditions. Nevertheless, the use of base-course mixtures having plasticity indexes over 6 is not advisable and it is the practice in North Carolina to require that sand-clay bases have plasticity indexes less than 6.
6. Repetition of failures in the same locations after repairs had been made demonstrates that an increase of 2 inches in the thickness of the surfacing and an increase of 3 inches in base thickness were not effective in correcting conditions resulting from inadequate drainage and excessive plasticity of the base course.

SPEED TRANSITION RAMPS ON A BRIDGED ROTARY

BY THE DIVISION OF HIGHWAY TRANSPORT RESEARCH, PUBLIC ROADS ADMINISTRATION

Reported by **ROBERT O. SWAIN**, Highway Engineer

THE EFFECT OF RAMPS to provide the speed transition between expressways and local streets was revealed in a study of a bridged rotary on the Shirley Highway just south of Washington, D. C. The Shirley Highway is a controlled-access expressway whose adequacy, like that of any expressway, is contingent on the mobility of vehicles at its interchanges. In order to obtain maximum mobility, speeds at the entrances and exits of the interchange must be consistent with speeds on the intersecting roads.

The bridged rotary on the Shirley Highway furnishes the interchange between the high-speed-designed expressway and the lower-speed streets that feed into a highly developed apartment-house community complete with a retail commercial area, as may be seen in the cover illustration. A view of the two ramps studied appears in figure 1, and their profiles are shown in figure 2.

The importance of the community adjacent to the rotary is evidenced in the distribution of traffic which is presented graphically in figure 3. More than 11,000 vehicles moved to and from the community on a peak day in June 1946. At present the highway serves local traffic only, as the completed section ends a short distance beyond the rotary. The highway, which consists of two 24-foot pavements, passes under an elliptical rotary with radii varying from 220 feet to 716 feet.

The design features [1] of the interchange are shown in figure 4, which also indicates the acceleration and deceleration ramps studied. The gradient and alinement of the ramp connections between the Shirley and the rotary were designed to enable rapid and safe acceleration and deceleration between two facilities used at different speeds. The two ramps studied were located on the north side of the interchange. The northwest ramp serves to decelerate traffic and is 615 feet long on a 3.8 percent average upgrade. The northeast ramp serves to accelerate traffic and is 510 feet in length on a 5.3 percent average downgrade.

Speed studies made during May and June 1946 disclosed that southbound traffic on the Shirley Highway averaged 37.5 mph (miles per hour) at a location just north of the bridged rotary. Upon entering the deceleration ramp, average speeds had been reduced to 35.1 mph. At the top of the ramp—the exit from the deceleration lane—the average speed was 22.5 mph, which was remarkably consistent with the average speeds of 22.8, 20.7, and 24.3 mph at three locations on the rotary.

The average speed of northbound vehicles on the rotary 300 feet from the entrance to the acceleration ramp was 24.3 mph. At the entrance to the acceleration ramp the average speed was 28.5 mph. The entrance speed to the Shirley Highway from the acceleration ramp was 36.6 mph, 1.1 mph higher than the average speed (35.5 mph) for northbound traffic on the Shirley Highway at a point just north of the interchange. The latter highway speed was observed near a railroad (service line) crossing. This may account for the slightly lower average speeds on the expressway. The average speed (28.5 mph) at the entrance to the acceleration ramp is higher than the average speed for the rotary, which may be due not only to the downgrade on this side of the rotary but possibly to the long tangent-effect approach (fig. 4) to the ramp from the southeast section of the rotary and the exceptionally good sight distance from the ramp which affords full

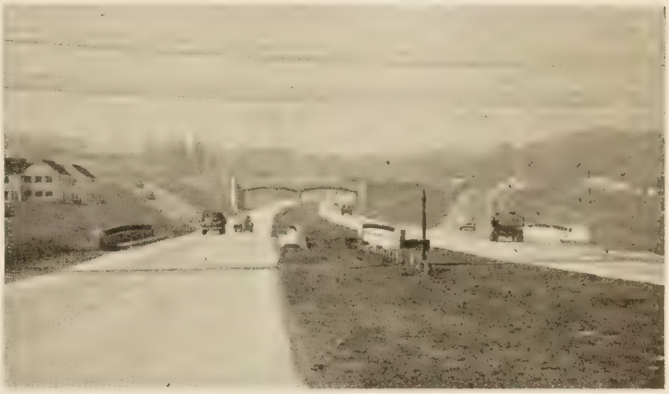


Figure 1.—The Acceleration and Deceleration Ramps Studied, Seen from the North.

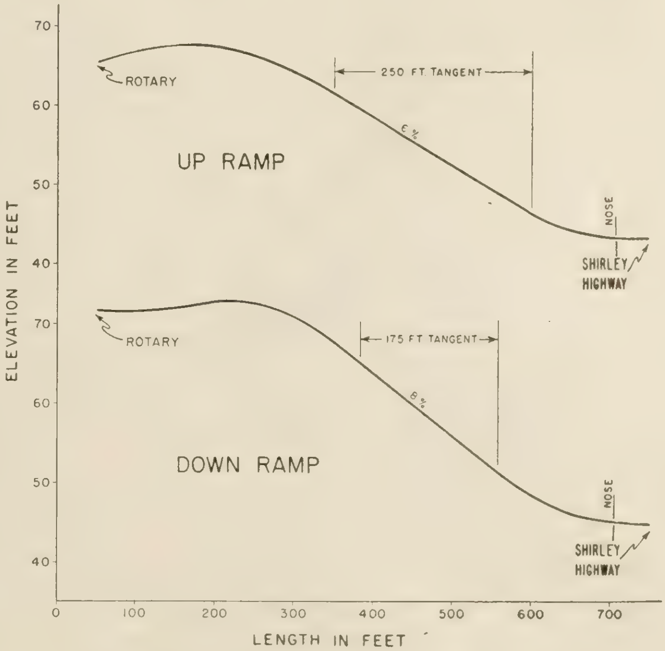


Figure 2.—Profiles of the Ramps Studied.

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[1] A discussion of the design features is given in *Two-Bridge Rotary Built for Controlled-Access Interchange*, by D. W. Loutzenheiser; Roads and Streets, vol. 89, No. 4, April 1946, p. 85.

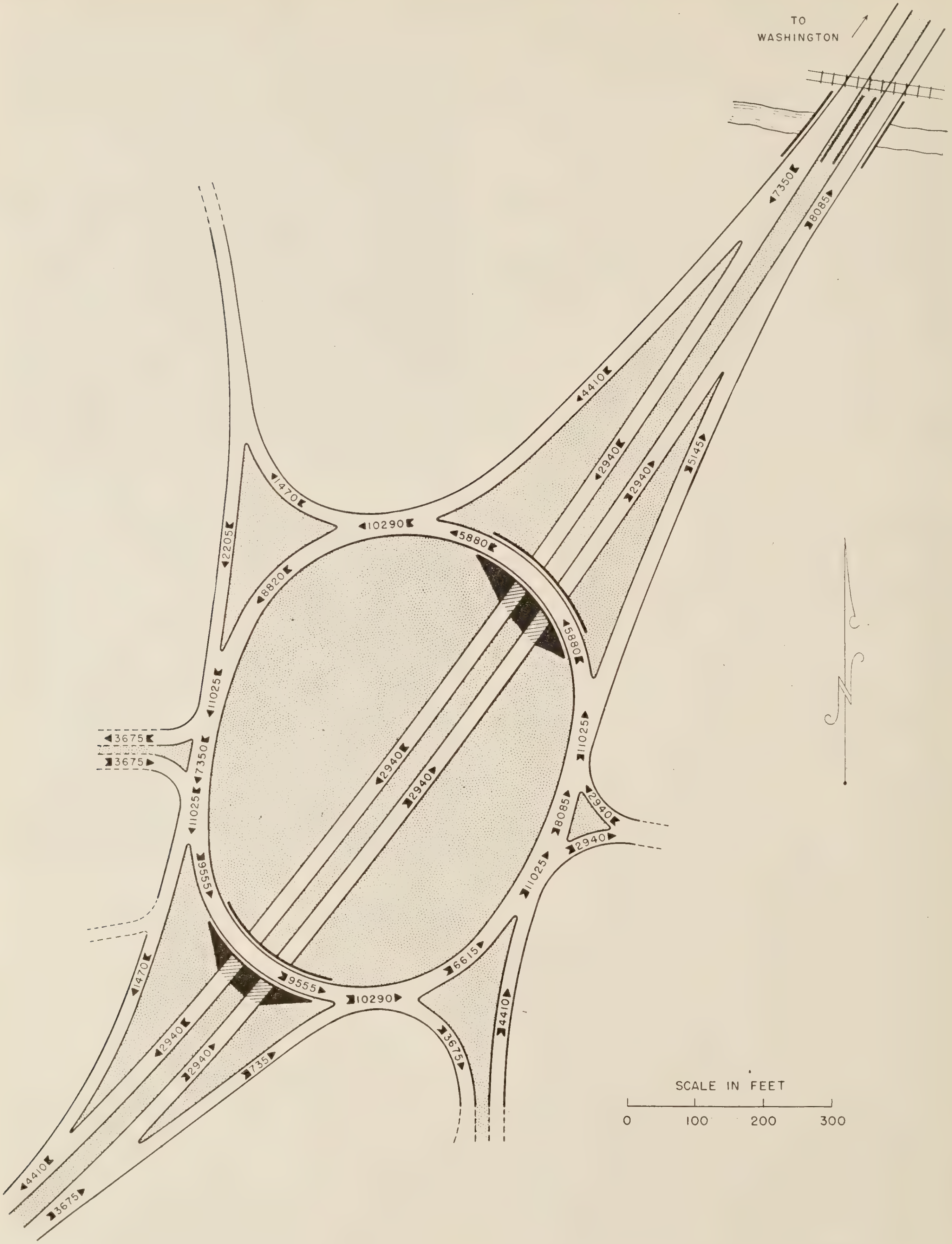


FIGURE 3.—TRAFFIC FLOW ON A PEAK DAY IN JUNE 1946 AT THE BRIDGED ROTARY, SHIRLEY HIGHWAY.

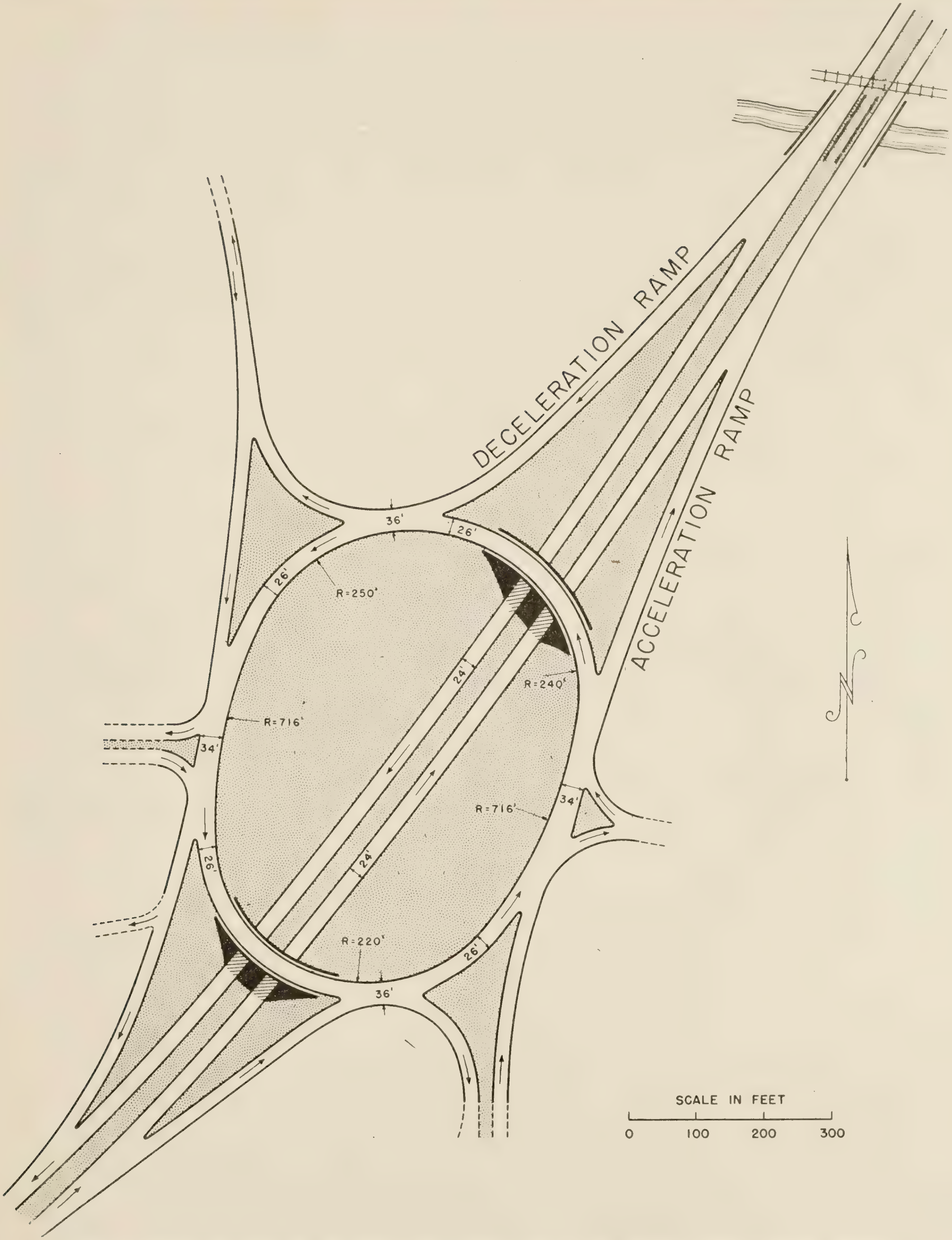
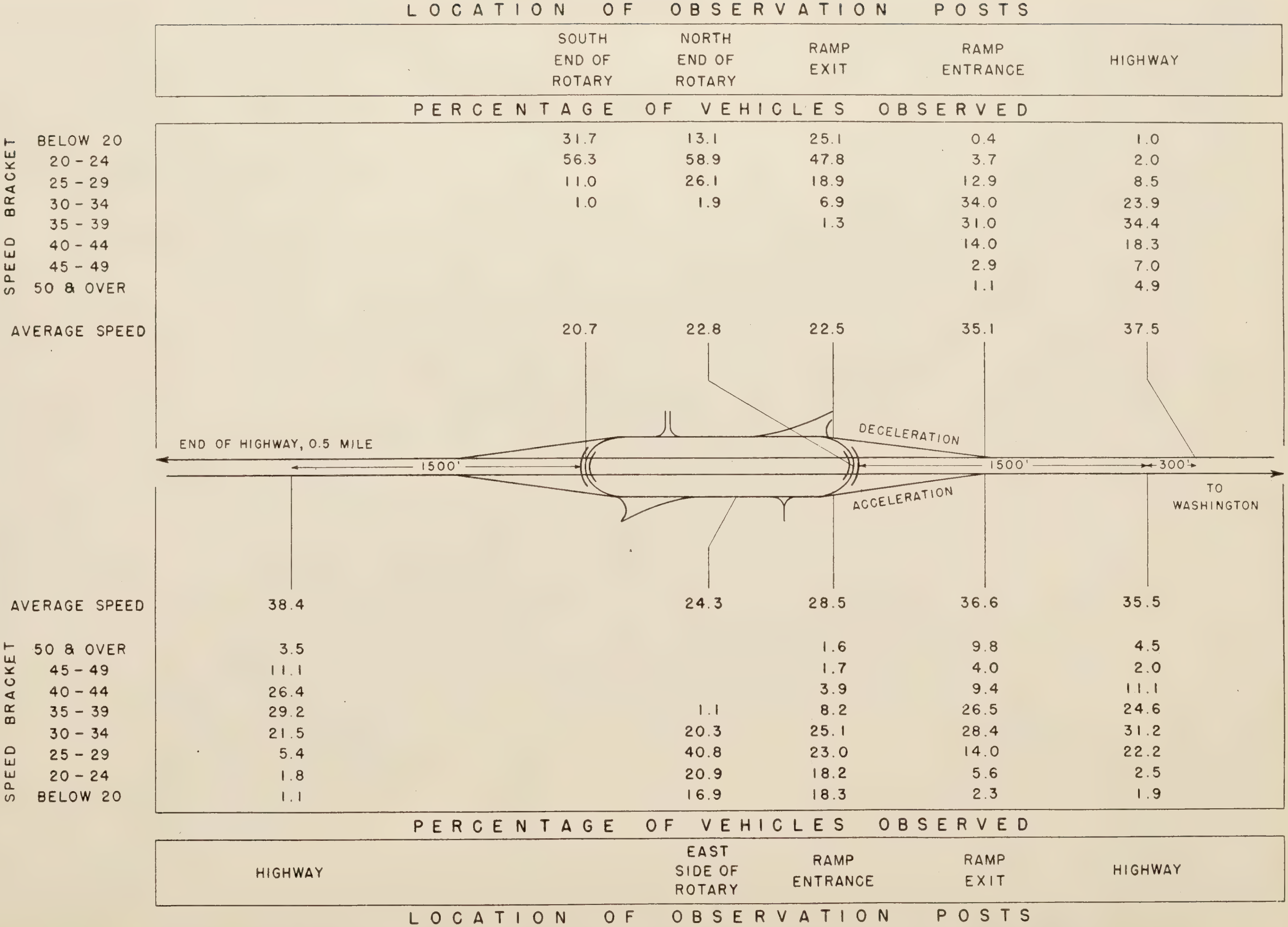


FIGURE 4.—DESIGN FEATURES AND LOCATION OF THE RAMPS STUDIED AT THE BRIDGED ROTARY, SHIRLEY HIGHWAY.



LOCATION OF OBSERVATION POSTS

PERCENTAGE OF VEHICLES OBSERVED

SPEED BRACKET	SOUTH END OF ROTARY	NORTH END OF ROTARY	RAMP EXIT	RAMP ENTRANCE	HIGHWAY
BELOW 20	31.7	13.1	25.1	0.4	1.0
20 - 24	56.3	58.9	47.8	3.7	2.0
25 - 29	11.0	26.1	18.9	12.9	8.5
30 - 34	1.0	1.9	6.9	34.0	23.9
35 - 39			1.3	31.0	34.4
40 - 44				14.0	18.3
45 - 49				2.9	7.0
50 & OVER				1.1	4.9
AVERAGE SPEED	20.7	22.8	22.5	35.1	37.5

SPEED BRACKET	HIGHWAY	EAST SIDE OF ROTARY	RAMP ENTRANCE	RAMP EXIT	HIGHWAY
AVERAGE SPEED	38.4	24.3	28.5	36.6	35.5
50 & OVER	3.5		1.6	9.8	4.5
45 - 49	11.1		1.7	4.0	2.0
40 - 44	26.4		3.9	9.4	11.1
35 - 39	29.2	1.1	8.2	26.5	24.6
30 - 34	21.5	20.3	25.1	28.4	31.2
25 - 29	5.4	40.8	23.0	14.0	22.2
20 - 24	1.8	20.9	18.2	5.6	2.5
BELOW 20	1.1	16.9	18.3	2.3	1.9

PERCENTAGE OF VEHICLES OBSERVED

LOCATION OF OBSERVATION POSTS

Figure 5.—Observed Speeds, May and June 1946, at the Bridged Rotary, Shirley Highway.

view of the expressway. A summary of the observed speeds is given in figure 5.

Using the approximate average entrance speed (35 mph) at the start of the deceleration ramp, a series of test runs was made up the grade in a modern, medium-weight, six-cylinder passenger car in order to determine the effect of: (1) a closed throttle, and (2) no change in the throttle opening.

With a starting speed of 35 mph, the passenger car failed by 25 feet to reach the top of the grade when the throttle was closed by removing the foot from the accelerator. The car remained in high gear. Repeating the 35 mph entrance speed, but maintaining a constant flow of fuel (no change in the throttle opening), the passenger-car's exit speed at the end of the deceleration ramp averaged 28 mph for a large number of test runs. Entrance speeds of 50 and 60 mph, using a closed throttle on the deceleration ramp, resulted in exit speeds of 14 and 24 mph, respectively.

The passenger-car test runs were also conducted on the acceleration ramp. A point on the rotary 300 feet from the entrance to the acceleration ramp, where the average speed of 24.3 mph was observed, was used as an index and starting point. Starting at 24 mph, one series of test runs showed an average speed of 23 mph at the entrance to the ramp and 30 mph at the exit—the ramp's connection with the expressway—when no change was made in the throttle opening. Another series of test runs in which the driver was instructed to assume a "gradual and safe" acceleration resulted in an exit average speed of 51 mph after a speed of 24 mph 300 feet in advance of the acceleration ramp and a speed of 31 mph at the entrance to the ramp.

The provision of an upgrade for deceleration and a downgrade for acceleration, together with the tangent effect of the ramps, contribute to easy usage which tends to favor a depressed expressway as a suitable facility for urban use, where it is essential that vehicle speeds on the expressway be reduced materially before entering a city street and where speeds of vehicles entering the expressway must be consistent with the modal speed pattern of the expressway.

HIGHWAY STATISTICS, 1945—A NEW BULLETIN

The Public Roads Administration has recently issued a new bulletin, Highway Statistics, 1945, in which are presented the series of statistical and analytical tables of general interest on the subjects of motor-fuel consumption, motor-vehicle registration, State highway-user taxes, financing of State highways, and highway mileage, for the calendar year 1945. The brief text included in the bulletin highlights information of particular interest or significance in the tables.

For many years the Public Roads Administration has prepared these annual tables and has distributed them individually. This practice will be continued so that the information on each particular subject can be made available at the earliest possible date. Issuance of the collected tables in bulletin form, however, makes the data more convenient and serviceable to users of highway statistics. It is intended to publish the bulletin annually in the future.

Highway Statistics, 1945 is for sale by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C., at 35 cents a copy.

TWENTY-FIVE YEARS OF FARM TRUCK OWNERSHIP

BY THE DIVISION OF HIGHWAY TRANSPORT RESEARCH, PUBLIC ROADS ADMINISTRATION

Reported by **C. D. BOHANNAN**, Highway Economist

NEARLY 1½ MILLION TRUCKS, equal to 30 percent of all privately owned trucks registered in the United States in 1945, are owned by farmers. The number of farm trucks reported in statistical data from the 1945 census of agriculture is 1,490,300, representing a 42.3 percent gain over 1940. This gain takes

TABLE 1.—*Number of trucks on farms, and number and percent of farms reporting trucks—1920 to 1945* [1]

Division and State	Number of trucks on farms					Farms reporting trucks							
						Number of farms				Percent of all farms			
	1945		1940	1930	1920	1945	1940	1930	1920	1945	1940	1930	1920
	Number	Percent of all trucks [2]											
United States	1, 490, 300	30. 8	1, 047, 084	900, 385	139, 169	1, 299, 350	944, 184	845, 335	131, 551	22. 2	15. 5	13. 4	2. 0
Geographic divisions:													
New England	74, 151	25. 2	51, 207	37, 972	8, 119	59, 372	42, 670	33, 328	7, 284	39. 5	31. 6	26. 7	4. 7
Middle Atlantic	148, 632	20. 3	116, 714	120, 789	22, 011	121, 457	101, 093	109, 756	20, 472	35. 0	29. 0	30. 7	4. 8
East North Central	240, 161	28. 2	191, 394	198, 172	26, 074	220, 357	177, 085	189, 040	24, 942	23. 1	17. 6	19. 6	2. 3
West North Central	285, 597	43. 5	199, 234	180, 857	33, 375	261, 765	186, 429	174, 764	32, 331	25. 4	17. 1	15. 7	2. 9
South Atlantic	175, 872	29. 3	116, 297	94, 946	15, 787	153, 630	104, 295	88, 019	14, 716	14. 7	10. 2	8. 3	1. 3
East South Central	105, 736	34. 2	71, 830	45, 568	5, 153	97, 566	66, 985	43, 234	4, 869	10. 2	6. 5	4. 1	0. 5
West South Central	187, 775	32. 7	121, 788	96, 791	9, 455	168, 660	112, 180	92, 300	8, 960	19. 2	11. 6	8. 4	0. 9
Mountain	118, 528	43. 3	75, 552	55, 742	7, 589	98, 600	67, 083	52, 488	7, 168	46. 4	28. 7	21. 8	2. 9
Pacific	153, 848	28. 2	103, 068	69, 548	11, 606	117, 943	86, 364	62, 406	10, 809	41. 8	31. 3	23. 8	4. 6
New England:													
Maine	17, 849	35. 4	13, 118	10, 781	1, 120	15, 229	11, 698	9, 879	1, 061	36. 1	30. 0	25. 3	2. 2
New Hampshire	9, 191	29. 1	6, 469	4, 539	717	7, 486	5, 489	4, 051	663	39. 8	33. 2	27. 2	3. 2
Vermont	9, 567	88. 0	6, 172	5, 035	616	8, 386	5, 451	4, 625	576	31. 7	23. 1	18. 6	2. 0
Massachusetts	18, 751	17. 1	12, 465	9, 572	3, 535	14, 589	9, 934	7, 982	3, 136	39. 4	31. 1	31. 2	9. 8
Rhode Island	3, 142	14. 5	1, 982	1, 701	536	2, 115	1, 453	1, 366	471	58. 7	48. 2	41. 1	11. 5
Connecticut	15, 651	22. 6	11, 001	6, 344	1, 595	11, 567	8, 645	5, 425	1, 377	52. 0	40. 8	31. 5	6. 1
Middle Atlantic:													
New York	69, 141	22. 7	55, 285	58, 974	9, 259	57, 049	48, 522	54, 084	8, 636	38. 2	31. 7	33. 8	4. 5
New Jersey	23, 220	15. 7	17, 106	14, 753	3, 380	16, 338	13, 590	12, 504	3, 075	62. 3	52. 6	49. 3	10. 4
Pennsylvania	56, 271	20. 2	44, 323	47, 062	9, 372	48, 070	38, 981	43, 168	8, 761	28. 0	23. 1	25. 0	4. 3
East North Central:													
Ohio	42, 808	21. 4	35, 169	39, 210	7, 319	38, 670	31, 872	36, 693	6, 960	17. 5	13. 6	16. 7	2. 7
Indiana	38, 411	26. 1	29, 732	30, 037	3, 671	35, 260	27, 409	28, 468	3, 501	20. 0	14. 9	15. 7	1. 7
Illinois	56, 629	26. 6	42, 515	40, 371	6, 154	52, 600	39, 970	38, 877	5, 907	25. 8	18. 7	18. 1	2. 5
Michigan	41, 303	27. 8	33, 095	36, 768	4, 886	37, 304	30, 311	34, 894	4, 681	21. 3	16. 2	20. 6	2. 4
Wisconsin	61, 010	42. 7	50, 883	51, 786	4, 044	56, 523	47, 523	50, 108	3, 893	31. 8	25. 4	27. 6	2. 1
West North Central:													
Minnesota	47, 413	41. 2	38, 617	36, 557	3, 803	44, 170	36, 101	35, 503	3, 677	23. 4	18. 3	19. 2	2. 1
Iowa	37, 386	36. 5	26, 352	32, 669	8, 910	35, 482	24, 947	31, 874	8, 669	17. 0	11. 7	14. 8	4. 1
Missouri	47, 225	30. 8	31, 771	20, 132	5, 059	44, 241	29, 845	19, 215	4, 878	18. 2	11. 7	7. 5	1. 9
North Dakota	36, 674	74. 4	21, 518	16, 990	774	32, 494	19, 937	16, 502	743	46. 7	27. 0	21. 2	1. 0
South Dakota	22, 230	59. 8	14, 269	14, 816	4, 353	20, 487	13, 472	14, 485	4, 249	29. 8	18. 6	17. 4	5. 7
Nebraska	33, 761	45. 4	24, 090	26, 045	6, 548	30, 792	22, 504	25, 176	6, 333	27. 6	18. 6	19. 4	5. 1
Kansas	60, 908	48. 8	42, 617	33, 648	3, 928	54, 099	39, 623	32, 009	3, 782	38. 3	25. 3	19. 3	2. 3
South Atlantic:													
Delaware	3, 800	28. 8	2, 567	2, 996	304	3, 110	2, 215	2, 781	283	33. 4	24. 6	28. 6	2. 8
Maryland	19, 197	27. 1	13, 058	11, 284	2, 805	16, 080	11, 454	10, 205	2, 556	38. 9	27. 2	23. 6	5. 3
District of Columbia	35	0. 3	39	81	29	24	32	57	29	60. 0	49. 2	54. 8	14. 2
Virginia	31, 956	36. 0	23, 272	19, 459	2, 544	27, 966	20, 818	17, 964	2, 389	16. 2	11. 9	10. 5	1. 3
West Virginia	16, 285	26. 7	12, 445	7, 432	936	14, 843	11, 485	6, 936	886	15. 2	11. 6	8. 4	1. 0
North Carolina	32, 924	32. 8	20, 621	18, 558	2, 671	30, 489	19, 279	17, 613	2, 551	10. 6	6. 9	6. 3	0. 9
South Carolina	15, 348	27. 7	8, 242	6, 966	1, 736	13, 296	7, 392	6, 575	1, 609	9. 0	5. 4	4. 2	0. 8
Georgia	34, 688	34. 2	21, 693	15, 967	3, 145	31, 250	19, 952	15, 036	2, 913	13. 8	9. 2	5. 9	0. 9
Florida	21, 639	22. 7	14, 360	12, 203	1, 617	16, 572	11, 668	10, 852	1, 500	27. 1	18. 7	18. 4	2. 8
East South Central:													
Kentucky	27, 194	33. 5	19, 100	7, 188	1, 538	25, 175	17, 830	6, 740	1, 455	10. 6	7. 1	2. 7	0. 5
Tennessee	26, 326	32. 8	18, 908	9, 039	1, 430	24, 659	17, 727	8, 563	1, 362	10. 5	7. 2	3. 5	0. 5
Alabama	23, 949	31. 3	15, 257	12, 838	1, 180	21, 939	14, 094	12, 169	1, 114	9. 8	6. 1	4. 7	0. 4
Mississippi	28, 267	39. 5	18, 565	16, 503	1, 005	25, 793	17, 334	15, 762	938	9. 8	6. 0	5. 0	0. 3
West South Central:													
Arkansas	33, 134	42. 2	19, 674	11, 000	1, 027	30, 304	18, 441	10, 526	973	15. 2	8. 5	4. 3	0. 4
Louisiana	20, 974	26. 8	17, 005	9, 281	874	18, 637	15, 663	8, 769	793	14. 4	10. 4	5. 4	0. 6
Oklahoma	44, 381	40. 4	28, 402	23, 930	2, 155	40, 910	26, 660	23, 039	2, 070	24. 8	14. 8	11. 3	1. 1
Texas	89, 286	29. 0	56, 707	52, 580	5, 399	78, 809	51, 416	49, 966	5, 124	20. 5	12. 3	10. 1	1. 2
Mountain:													
Montana	29, 388	61. 6	21, 037	14, 615	1, 225	23, 661	18, 332	13, 783	1, 167	62. 7	43. 8	29. 0	2. 0
Idaho	19, 096	49. 6	12, 002	6, 281	837	16, 576	10, 941	5, 986	779	40. 0	25. 1	14. 4	1. 9
Wyoming	8, 917	44. 1	6, 341	4, 108	591	7, 424	5, 553	3, 820	554	56. 8	37. 0	23. 9	3. 5
Colorado	28, 794	40. 1	16, 850	16, 918	3, 016	24, 057	15, 119	16, 052	2, 884	50. 5	29. 4	26. 8	4. 8
New Mexico	11, 902	40. 0	7, 117	5, 328	593	10, 256	6, 368	5, 024	552	34. 5	18. 7	16. 0	1. 8
Arizona	6, 859	23. 3	4, 284	3, 062	581	5, 008	3, 561	2, 719	527	38. 1	19. 3	19. 2	5. 3
Utah	10, 969	40. 9	6, 238	4, 189	572	9, 720	5, 801	3, 986	544	36. 9	22. 8	14. 7	2. 1
Nevada	2, 603	27. 4	1, 683	1, 241	174	1, 898	1, 408	1, 118	161	55. 4	39. 4	32. 5	5. 1
Pacific:													
Washington	40, 034	39. 1	28, 228	18, 836	3, 371	32, 730	24, 886	17, 622	3, 172	41. 0	30. 5	24. 9	4. 8
Oregon	28, 118	34. 1	16, 825	9, 741	1, 819	23, 253	14, 904	9, 110	1, 728	36. 8	24. 1	16. 5	3. 4
California	85, 696	23. 8	58, 015	40, 971	6, 416	61, 960	46, 574	35, 674	5, 909	44. 6	35. 1	26. 3	5. 0

[1] Data from censuses of agriculture for 1920, 1930, 1940, and 1945.
[2] "All trucks" are truck registrations by States as reported to Public Roads Administration, excluding publicly owned vehicles (table MV-1, 1945).

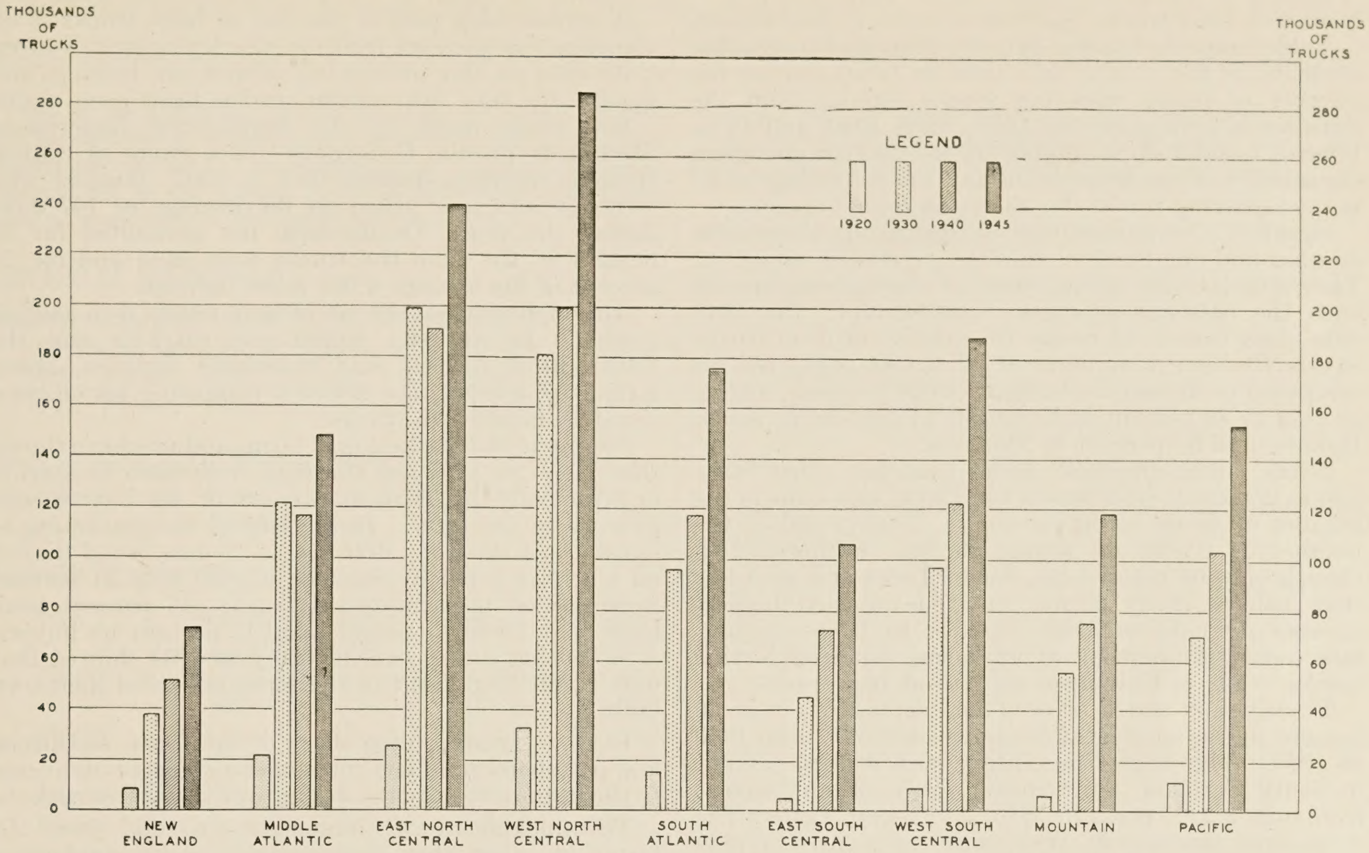


FIGURE 1.—NUMBER OF TRUCKS ON FARMS, BY GEOGRAPHIC DIVISION—1920 TO 1945.

on added significance when it is recalled that as a war measure civilian truck manufacture and sales were frozen after March 1942.

Another indication of the growth of farm truck ownership is the increase in the percentage of farms reporting trucks owned, from 15.5 percent in 1940 to 22.2 percent in 1945.

Twenty-five years ago (1920) only 2 percent of the Nation's farms reported trucks. In that year the total number of farm trucks was 139,169 or 13.8 percent of the

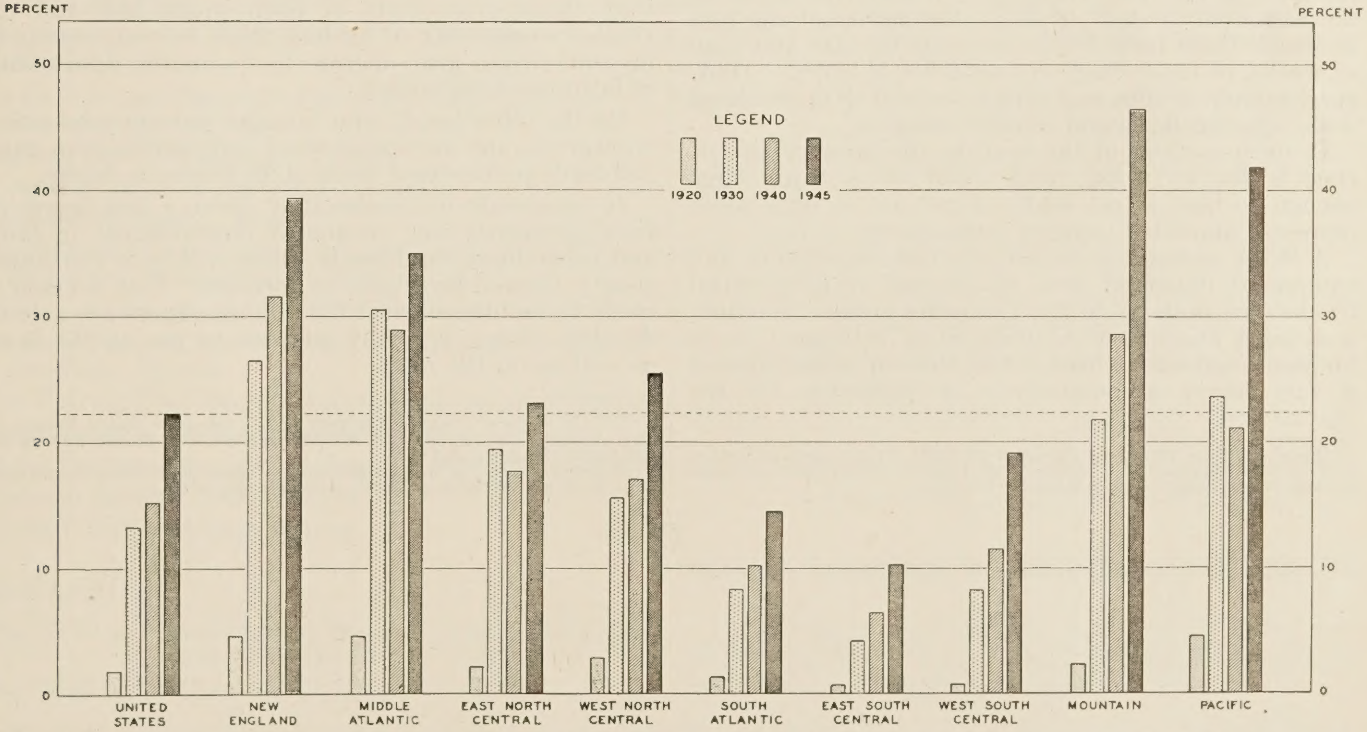


FIGURE 2.—PERCENT OF FARMS REPORTING TRUCKS OWNED, BY GEOGRAPHIC DIVISION—1920 TO 1945.

estimated total truck registration in the United States.

Table 1 reports detailed data, by State and geographic division, on the number of trucks on farms and on the number of farms reporting trucks owned, from the censuses of agriculture for 1920, 1930, 1940, and 1945. Figures 1 and 2 show graphically the 25-year change in the number of trucks on farms and the percentage of all farms reporting trucks, for each geographic division.

Significant variations from one geographic division to another and one State to another are readily apparent. The State data also permit some interesting comparisons with the national averages. For example, the 1945 data show that in 15 States the number of farm trucks equals 40 percent or more of all trucks registered, as compared to the national average of 30 percent, ranging as high as 88 percent in Vermont, 74 percent in North Dakota, and 62 percent in Montana.

Texas, containing more farms than any other State just as it exceeds all others in total area, also leads in the number of farms reporting trucks, 78,809, and in the number of trucks on farms, 89,286. California, although only 60 percent the size of Texas and with less than half as many farms, reported the next highest number of trucks on farms, 85,696. In Texas, furthermore, only 20 percent of all farms reported having trucks, while in California 45 percent had trucks.

Twenty-one States showed an increase of over 50 percent in the number of farm-owned trucks from 1940 to 1945. The largest percentage gain was 86 percent in South Carolina, representing, however, an increase from only 8,242 trucks in 1940 to 15,348 in 1945. The 20-percent increase in Wisconsin represented a gain from 50,883 trucks in 1940 to 61,010 in 1945.

In only seven States did half or more of the farms report having trucks. One of these was New Jersey, which in 1940 was the only State in which over 50 percent of the farms had trucks.

On the whole, this record of 25 years of farm truck ownership portrays the growing importance of trucks in farm operations. Adequate Nation-wide data are not available to show in detail the nature of the uses to which these farm trucks are put, the size and kind of trucks, or the average annual miles of travel. However, sample studies and certain related data do throw some light on these and kindred subjects.

In most sections of the country the farmers' preference is for a 1½-ton truck—that is, a truck large enough to haul a real load and yet not so large as to represent unneeded capacity and expense.

A WPA technology report [1] on farm machinery and equipment indicated that 80 percent of farm-owned trucks were in the 1- to 2-ton capacity group. Further, a detailed analysis of State-by-State estimated needs for additional farm trucks during the war period showed a very heavy preponderance of preference for the 1½-ton size.

A considerable part of the use of farm trucks is on the farm, as distinct from on the highway. Nation-wide data on this interesting subject are lacking, and apparently very few sample studies have been made.

One study made by the Agricultural Experiment Station at Purdue University [2] in a group of central Indiana counties showed that in 1937, farmers who owned trucks used them on the average of 197 days during the year. On-the-farm use accounted for 55 percent of the time the trucks were used and for 28 percent of the average 4,061 miles traveled.

Although much of the use of farm trucks is in hauling products to shipping points and markets and the return haul of farm and household supplies, many farmers in some of the heaviest producing agricultural counties do not own trucks.

Studies of the marketing of farm products have shown that for some products the haul from farm to market is principally by for-hire carriers or by buyers who pick up at the farm. In a study of the marketing of livestock in the Corn Belt States [3] it was found that of all hogs marketed by farmers in 1940 only 21 percent were hauled in farm-owned trucks, 66 percent were hauled by for-hire truckers, and 13 percent by buyers. A Wisconsin study covering the year 1937 showed that only about 30 percent of the farmers hauled their own milk.

In some areas a large share of the feeds, fertilizers, and petroleum products consumed on farms is delivered to the farms either by the dealers or by for-hire truckers.

This movement of commodities to and from the farms in other than farm-owned trucks emphasizes the fact that the condition of farm roads is of vital concern not only to the farmers who live along them but also to those business firms and individuals who buy from and sell to farmers, and to the for-hire truckers who furnish the necessary transportation services.

The exact extent of future farm truck ownership is, of course, impossible to predict. It is conceivable that changes in kinds of farm production and increased availability of for-hire truck service, especially in some areas, may operate to lessen the desirability of farm truck ownership.

On the other hand, some changes in farm production enterprises and increased rural industrialization may call forth an increased demand for trucks on farms.

It seems safe to assume that, given a fair degree of farm prosperity and continued improvement in farm and other local rural roads, there will be a continued steady demand for trucks by farmers. This demand is likely to be intensified if the manufacturers are able to develop trucks especially adapted to use on the farm as well as on the road.

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[1] *Changes in Farm Power and Equipment: Tractors, Trucks, and Automobiles,* by E. G. McKibben and R. A. Griffin; Works Progress Administration, National Research Project Report No. A-9, December 1938, p. 44.

[2] *The Use of Farm Trucks in Marketing Farm Products in Central Indiana,* by T. K. Cowden; Purdue University Agricultural Experiment Station Bulletin No. 443, August 1939, pp. 11 and 12.

[3] *Marketing Livestock in the Corn Belt;* South Dakota State College Agricultural Experiment Station Bulletin No. 365, November 1942, p. 166.

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Public Control of Highway Access and Roadside Development (revision). 35 cents.
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No. 315 . . . Moments in Simple Span Bridge Slabs With Stiffened Edges.
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No. 345 . . . Ultimate Strength of Reinforced Concrete Beams as Related to the Plasticity Ratio of Concrete.
No. 346 . . . Highway Slab-Bridges with Curbs: Laboratory Tests and Proposed Design Method.
No. 363 . . . Study of Slab and Beam Highway Bridges.

UNIFORM VEHICLE CODE

Act I.—Uniform Motor-Vehicle Administration, Registration, Certificate of Title, and Antitheft Act.
Act II.—Uniform Motor-Vehicle Operators' and Chauffeurs' License Act.
Act III.—Uniform Motor-Vehicle Civil Liability Act.
Act IV.—Uniform Motor-Vehicle Safety Responsibility Act.
Act V.—Uniform Act Regulating Traffic on Highways.

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